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Energy consumption pattern of a decentralized community in northern Haryana

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Abstract

A survey of household energy consumption pattern has been carried out in a village, Bibipur, district Jind, Haryana, India, during 2004. The households surveyed covered heterogeneous population belonging to different income groups, education groups and social groups. Studies were made on the total energy available, total energy required and energy consumption in different sectors domestic, agricultural, transport, rural industries and miscellaneous uses. The total energy available from all the sources (animate, biomass/non-conventional and inanimate sources) in the village is 468,205 MJ and the requirement for all the activities and from all the resources is 592,220 MJ. There is a big gap between energy supply and demand for the village. There is more availability of non-conventional energy resources as compared to conventional energy resources and some resources are unexploited. Therefore, to meet the balance of energy demand and supply, non-conventional resources should be exploited.

In domestic sector, maximum energy is used in cooking (52.1%) and 45% of it is supplied from non-conventional energy sources and 10% from conventional energy sources. Calculations were made by considering all the energy resources for average per capita energy consumption and it was 20.02 MJ/day per capita. Electricity is used mainly for lighting and power, while gas is preferred for cooking.

In agricultural sector, energy consumption for different activities was calculated and it was found that maximum energy consumption is in irrigation (41.7%) and minimum in transplanting. In agricultural sector, maximum energy comes from conventional energy sources (about 60%) and from non-conventional energy sources it is only about 30%. From the study, it was found that maximum population having good economic conditions like electricity very much as an energy source followed by LPG, biogas, coal, firewood and agricultural residues.

Keywords: Energy; Energy consumption; Energy demand; Energy sources; Energy supply; Rural areas

Contents

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1. Introduction

Seventy percent of India's population live in its rural areas distributed over 580,000 villages [1]. Obviously, a substantial portion of the total energy demand in the country is in rural sector [2–5] and biomass is the fourth largest energy source in the world and the first in India [6]. In the absence of conventional energy supply the rural economy lacked adequate growth. A comparative assessment shows that the household sector accounts for 30–75% of the energy consumption in our country whereas in the developed countries it is 25–30%. About 90% of the household energy goes for cooking food [7], which is largely obtained by burning the biomass fuel. Among biomass energy sources, dung-cake is contributing about 60% of the total cooking energy needs followed by firewood, which is 49% for the domestic sector use. Conventional fuel like LPG has achieved very little penetration in the rural domestic sector.

In the past, a large number of energy consumption surveys have been conducted and from this an important inference is that 180 million tons of firewood, 40 million tons of dung-cakes and 30 million tons of agricultural residues were consumed in the rural sector for meeting the domestic thermal energy requirement in 1991 [8]. Thus, bulk of the rural energy demand for domestic sector is met from woodfuel, vegetable and animal waste in rural India [8–11] and also in other under-developed and developing countries. The degree to which the population relies on agricultural residues for fuel varies among the villages. The heterogeneity of income distribution is an important indicator of fuel-consumption pattern of the rich and poor and their inclination for energy resource utilization are non-biomass and biomass based, respectively, as there is a good correlation between income and fuel consumption [4]. Generally, 15–35% income of a household is spent on fuel though this excluding manpower energy in terms of the time spent in gathering fuel [9].

Other developing countries like China, which is a big agricultural country and has most abundant straw resources in the world, produced more than 620 million tons of straw in 2002, and indicates that about 33–45% of energy consumption in rural areas in domestic sector is met from straw [12,13] and 40.14% by conventional energy. In Bangladesh, fossil fuel reserves are very less and about 80% of the total energy supply comes from biomass [14,15] and there is a good opportunity to trap the wind energy in coastal region and also solar energy, which is abundant. For remote areas, these are the good energy sources for rural electrification in Bangladesh. In South Africa, most people depend on fuelwood for meeting domestic energy needs [16]. In Zambia, firewood contributes about 66% of energy consumed in the country [17] and electricity consumption percentages for transportation, mining, industry, household, agriculture and services sectors and 49%, 27%, 14%, 4%, and 3%, respectively.

Other major sectors requiring energy in rural areas are agriculture, rural transport and rural industries. During the past five decades, the energy consumption pattern in the agricultural sector has drastically increased. The energy is supplied by animate and inanimate sources. The animate sources include human labour and animal power from bullocks, buffaloes, asses and horses. Inanimate energy in this sector is obtained from diesel engines (tractors, engines for water pumping, etc.) and electrical motors. Energy needs for rural transport and rural industries are met from diesel engines and electric power, wherever it is available [18].

Adequate capital investments and intensive research and development must be undertaken to provide adequate future energy for the future generations of Asian countries [19]. Efforts are in progress for creating awareness among the people for use of non-conventional- energy resources [20] even in the country like Indonesia where oil is abundant and heavily subsidized keeping in mind environmental sustainability. An energy utilization system based on local resources can improve productivity and standards in all spheres of rural living by encouraging local skills and participation, especially of artisans and women, and can also be supplemented by appropriate training and monitoring for efficient and safe use of biomass energy [21].

Village is rich in biomass-based energy resources (non-conventional energy), and so far it has not been trapped and used properly. Thus, efforts for promoting efficiency in energy use in this area stem primarily from socio-economic and environmental consideration and it may be possible by educating people on the energy problem and raising awareness of its importance. Campaign is now being intensified to reach directly the consumers in all social strata of the population. To use the dung optimally, for energy as well as for fertilizer, biogas technology may be introduced, but it has to be integrated after considering all the other aspects. Also solar energy can be used which is abundant.

For rural areas, energy planning involves use of a mix of locally available renewable resources with some conventional resources to meet the energy needs of the population. Such exercises are economically attractive in other developing countries also, whereby, the foreign exchange reserves for the purchase of conventional energy is curtailed.

The first step in the implementation of an energy planning exercise is to understand the energy consumption and utilization habits of the population being served. Frequently, an assessment of the levels of inequality in the consumption of various resources is necessary as this provides the rural planner with an understanding of the future trends and thus forearms him with strategic alternatives to combat any future energy resource crisis that the trends seem to imply.

In the present paper, an attempt is made to assess the energy resource available and consumption pattern in a typical North Indian rural-plain village. The population is

segregated into different categories based on their income levels and certain socio-economic criteria, which also have an influence on consumption levels of energy. The results of the analysis are then discussed in the light of the findings.

2. Material and methods

The rural site selected for the present investigations is Bibipur village, in district Jind, Haryana, India, which is nearly 150 km from Delhi in the northwest direction as shown in Fig. 1. It was surveyed in 2004 and data were collected on, through door-to-door survey of 500 households, population, number of houses, energy consumption pattern, energy supply and demand on the basis of their existing facilities, such as availability of various energy sources, educational facilities social hierarchy, etc. as shown in Table 1. The village has heterogeneous population belonging to many income and social groups; male-to-female ratio was 1400/1270. The residents were asked questions to know their opinion about the demand and supply of basic commodities like water and energy supply for this village.

Studies were made for the total energy available in terms of megajoule from all the available energy resources like animate sources (human power, animal power—bullocks, he-buffaloes, asses and horses), non-conventional energy sources/biomass (firewood, cow-dung, biogas) and inanimate sources (diesel, petrol, coal, kerosene, electricity and LPG) by using the conversion factors from Table 2 [18]. Energy demand and supply and the consumption pattern in the village in different sectors like domestic, agricultural, transport, rural industries and miscellaneous was also calculated. In domestic sector, emphasis was on contribution of different energy sources (firewood, cow-dung, coal, biogas, kerosene, LPG and electricity) on percent basis to different domestic activities like lighting, cooking, warming in winter, animal food preparation, water heating and miscellaneous. In agricultural sector, energy consumption

Table 1
Features of Bibipur village, district Jind, Haryana state, obtained from the survey conducted in December 2004

Description	Comments
Total land area	4400 acres
No. of houses	445
Human population	2670
Male to female ratio	1000:780
Animal population	2225
Education—literacy rate	Illiterates, 50%; matric, 35%; graduates, 10%; postgraduates, 5%
Energy resources	Biomass (wood agricultural residue and cow-dung), electricity, coal, kerosene oil, petrol, diesel, LPG, animal and muscle power
Rural industries and conventional activities	four cotton weavers, three pot makers, one saw mill, one dabha (restaurant), one paper mill, six blacksmiths, one goldsmith, five wood processors and 22 grocery shops and general stores
Major crop types	Wheat, cotton, paddy, barely, maize, jowar, barsim, sugarcane, gram and mustard, etc.
Drinking water sources	100% ground water: Government water taps—120, own hand pumps—90, water well—4
Water consumption	Total water consumption: 186.0 m^3/day
Wastewater generated	150 m^3/day

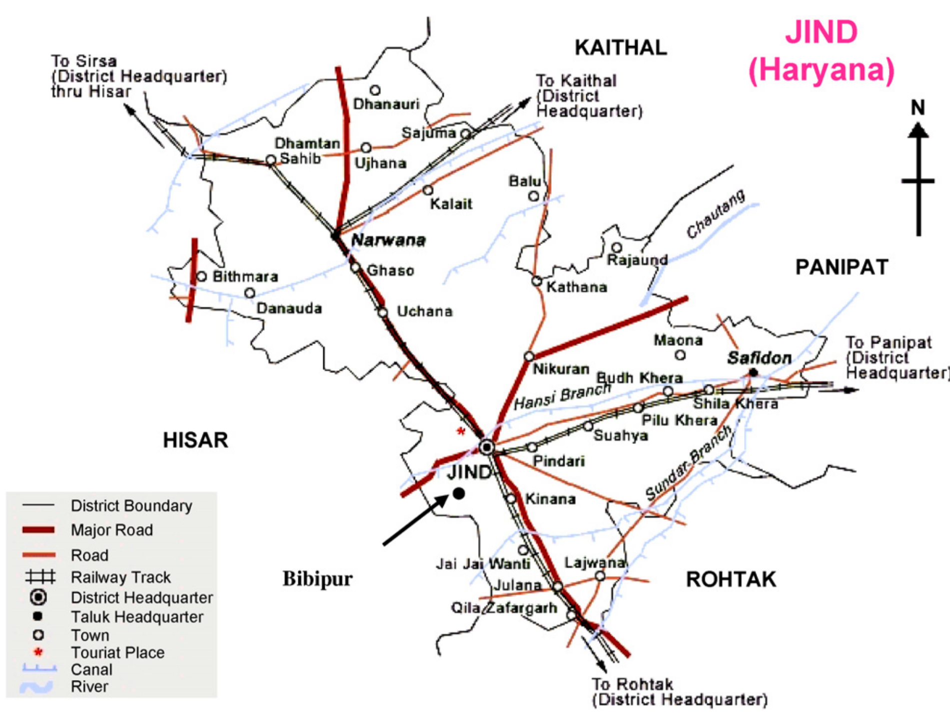


Fig. 1. Map of the studied site.

for different practices like tilling, seeding, transplantation, inter-culturing, weeding, harvesting, threshing and transportation was calculated and contributions of different sources like human power, animal power, tractor/motor/engine (diesel/petrol) in percent for these agricultural practices, were calculated. Human and animal power have been the traditional sources of farm power and energy. With the advent of mechanical and electrical sources of power, animal energy has been replaced with tractors, diesel-powered stationary engines and electric motors. However, a large part of the developing world still uses animal power for different stationary and mobile jobs related to agriculture. Main energy sources for the agricultural sector in the village are: manual power, diesel, petroleum and electricity. The energy for agricultural sector is usually provided in the form of human power, animal power, tractor, motor/engine, for pesticides and fertilizers.

Calculations were also made of the contribution of conventional and non-conventional energy sources to different sectors, like domestic, agricultural, transport, rural industries and miscellaneous, as a percentage and we also predicted the attitude of the people of the village from their responses towards different energy sources.

3. Result and discussion

From the survey of the village, it was found that it is a medium-size village having a heterogeneous population belonging to different income groups, education groups and social groups. The other important data on the village: total land area of 4400 acres, total number of houses 445, human population 2670, male-to-female ratio 1000/780, animal population 2225 and literacy rate is medium, shown in Table 1. The energy resources include biomass (cow-dung, firewood, agricultural residues, etc.), animate sources (animal and muscle power), inanimate sources (electricity, diesel, petrol, coal, kerosene oil and LPG).

3.1. Energy demand and supply

The total energy available from all the sources (animate, biomass/non-conventional and inanimate sources) in the village is 468,205 MJ and the requirement for all activities and from all resources is 592,220 MJ as shown in Table 3. It is clear from Table 3 that maximum energy available in the village is derived from biomass followed by inanimate and animate sources. It can also be depicted from Table 3

Table 2
Energy conversion factor

Particulars	Units	Equivalent (energy in MJ)	Remarks
A. Inputs			
1. Human labour			
(a) Adult men	Man–hour	1.96	
(b) Women	Woman–hour	1.57	1 Adult woman = 0.8 adult man
(c) Children	Child–hour	0.98	1 child = 0.5 adult man
2. Animals			
(a) Bullocks			
(i) Large	Pair–hour	14.05	Body weight above 450 kg
(ii) Medium	Pair–hour	10.10	Body weight 352–450 kg
(iii) Small	Pair–hour	8.07	Body weight less than 350 kg
(b) He-buffalloes	Pair–hour	15.15	He-buffallo = 1.5 medium bullock
(c) Camel or horse	Animal–hour	10.10	Camel or horse = medium *bullock pair*
(d) Mules and other	Animal–hour	4.04	Small animal = 0.4 medium bullock pair small animals
3. Diesel	1 L	56.31	Includes the cost of lubricants
4. Petrol	1 L	48.23	It includes the cost of lubricants
5. Electricity	1 kWh	11.93	
6. Machinery			
(a) Electrical motor	1 kg	64.80	Distribute the weight of the
(b) Primemovers	1 kg	68.40	
(c) Farm machinery	1 kg	62.70	
7. Chemical fertilizers			
(i) Nitrogen	1 kg	60.60	
(ii) P_2O_5	1 kg	11.1	
(iii) K_2O	1 kg	6.7	
8. Farm yard manure	1 kg	0.3	Dry matter
9. Chemicals			
(i) Superior	1 kg	120	Chemical requiring dilution at the time of application
(ii) Zinc sulphate	1 kg	20.9	
(iii) Inferior	1 kg	10.0	

Source: Mittal et al. [18].

that maximum demand for energy is from inanimate sources followed by biomass and animate sources.

3.2. Energy consumption pattern

Obviously, main energy consuming sectors in the village are domestic, agricultural, rural transport and rural industries. Energy consumption in these sectors is described below.

3.2.1. Domestic sector

The energy in the domestic sector is obtained from non-conventional as well as conventional energy sources like cow-dung, firewood, coal, biogas, kerosene, LPG and electricity and for different domestic uses, they contribute differently. Cooking is the largest energy consuming end use. It accounts for nearly 52.51% of the total domestic energy consumption as shown in Table 4. It was found that in villages about 98% of the households rely on biomass as cooking fuel because agricultural residues, cow-dung and wood-based cooking material are available in their area and is cheap also. Energy consumptions for water heating and preparation of food for animals and 16.22% and 16.32%, respectively. These values are average of the seasons: in winter, more energy is required for each activity, especially for water heating. The energy used for preparing the animal feed depends on the number of animals and the feed material (cooked or uncooked food). The energy for feeding an animal is somewhat higher than the energy consumed in cooking for a person. Adding mixed fodder may significantly reduce energy consumption. The thermal efficiencies of different wood stoves (chullah) using straw is about 9–10%, it is 30% for coal angithees (stoves), for biogas conversion 35% and for LPG 85%.

Table 3
Total energy available (supply) from all the resources and required (demand) for different sectors in village Bibipur per day

Sr. no.	Energy resources	Energy available (supply) (MJ)	Energy required (demand) (MJ)
1.	Animate		
	Human labour	25,500	10,220
	Animal power (bullocks, he-buffaloes, asses and horses)	100,150	50,120
2.	Biomass		
	Firewood	120,180	45,800
	Cow-dung	25,700	12,200
	Biogas	10,780	2900
3.	Inanimate		
	Diesel/petrol	60,450	150,000
	Electricity	120,325	300,200
	LPG	5120	20,780
	Total energy from all resources	468,205	592,220

3.2.2. Agricultural sector

This sector includes the total energy used in various practices for different activities like soil preparation (tiling), seeding, transplantation, irrigation, inter-culturing, weeding, harvesting, thrashing and transportation. The energy consumption shares (in percentage) for different energy sources in different agricultural activities are different. Through the study it is found that irrigation and tiling activities consume maximum energy as reported in Table 5 and it is about 41.7% for irrigation and 35% for tiling.. Tractor, diesel powered electric engines, electric powered tube wells and muscle power provide major energy shares for agriculture. Other agricultural activities like seeding, transplanting, inter-culturing, weeding, harvesting, threshing and transportation consume comparatively less energy than in irrigation and tiling as shown in Table 5. Non-conventional energy, i.e. human power, animal power and energy used for organic fertilizers and pesticides, contribute, significantly to agricultural activities, though conventional sources provide a major share.

From the study it was found that most of the energy consumption is in agricultural sector followed by domestic, rural industries and rural transport as shown in Table 6. The sector-wise energy consumption from the conventional and non-conventional sources is also depicted in Table 6 and it is evident from that non-conventional energy sources have more contribution to the domestic sector and is 45%

Table 4
Energy consumption pattern in various household activities from different energy sources on percent basis

End use	Energy consumption (on % basis)							
	Firewood	Cow-dung	Coal	Biogas	Kerosene	LPG	Electricity	Total (%)
Lighting	0	0	0	0	2.8	0	9.0	11.8
Cooking	20.21	19.5	0.50	2.98	0.55	7.96	0.81	52.51
Warming (mainly in winter)	0.90	1.06	0	0	0	0	0	1.96
Animal feeding	6.85	8.66	0	1.63	0	0	0.98	16.32
Water heating	5.36	7.48	0	0.83	0	0	2.55	16.22
Remainder	0	0	0	0.47	0	0	0.72	1.19
Total (%)	33.32	34.9	0.50	5.91	3.35	7.96	14.06	100

Table 5
Energy consumption pattern in various agricultural activities from different energy sources on percent basis

End use	Energy consumption (on % basis)						
	Human power	Animal power	Tractor	Motor/engine	Fertilizers	Pesticides	Total (%)
Tiling	7.6	3.2	24.2	0	0	0	35.0
Seeding	1.0	0.7	2.23	0	1.7	0.5	6.2
Transplanting	0.4	0	0	0	0	0	0.4
Irrigation	10.2	0	6.5	25.0	0	0	41.7
Inter-culturing	0.98	0	0	0	0	0	0.98
Weeding	0.20	0	0	0	0	0.32	0.52
Harvesting	3.5	0.3	2.5	0	0	0	6.3
Threshing	1.5	0.8	3.7	0.2	0	0	6.2
Transportation	0.8	0.5	1.4	0	0	0	2.7
Total (%)	26.18	5.5	40.6	25.2	1.7	0.82	100

Table 6
Contribution of conventional and non-conventional sources of energy in different sectors

Sectors	Conventional sources (%)	Non-conventional sources (%)	Total consumption (%)
Domestic	10	45	55
Agriculture	60	30	90
Transport	16	14	30
Rural industry	8	12	20
Miscellaneous	2	3	5

Table 7
Attitude towards different kinds of fuels in percent for domestic sector

Attitude	Agricultural residues	Firewood	Coal	Biogas	LPG	Electricity
Like very much (%)	25.8	35.5	10.8	35.8	80.8	99.5
Like (%)	60.5	34.0	51.3	23.4	11.3	0.5
Do not like (%)	13.7	30.5	37.9	40.8	7.9	0

and contribution of conventional sources is more in the agricultural sector and it is 60%. In rural transport and rural industries, both conventional and non-conventional sources contribute almost equally with a slight tilt towards conventional energy sources is the transport sector.

We have also assessed attitude of the people towards different energy sources in domestic sector, shown in Table 7. The key points in the assessment were about the accessibility and utility of different energy sources for household activities like agricultural residues, electricity, kerosene, firewood, LPG, biogas, diesel and coal. Table 6 represents the attitude of the population for various energy sources in domestic sector and it showed that 99.5% of well to do families like electricity but poor people do not like due to high price. 60.5% of families surveyed liked agricultural residues because it is a cheaper fuel available as a by-product in farming. During the survey families were asked, "What should be done to fulfill the requirement of your household energy since it is in short supply? And if financial assistance was given what options they would prefer to meet the energy shortage?" Of the respondents 6.6% said that they would reduce energy consumption, 5.8% said they would buy agricultural residues, 15.3% preferred to collect more biomass, while 42.5% and 50.5%, respectively, preferred LPG and electricity. The increase in the consumption of more electricity and LPG in the village is due to awareness, education and betterment in the financial conditions.

It is, however, impossible to completely replace the non-conventional energy for rural households by conventional energy within a short period of time. It is expected that within the coming decade or so, as per capita effective energy demand is increasing slowly, LPG consumption will be further increase, and it will be the major effective cooking energy source. Coal will be used by fewer and fewer households, and it will not be used as a supplementary energy source.

4. Conclusion

A survey was done on energy supply, demand and consumption pattern of Bibipur village during 2004. Studies were done on total energy available, total energy required and energy consumption in different sectors of the village. From is study, it was found that the non-conventional, as well as conventional, energy sources are used in different sectors. Total exploited reserve from all resources in the village is 468,205 MJ and the requirement is 592,220 MJ. There is a large deficiency of energy resources in the village. There is more availability of Non-conventional energy resources are available more compared to conventional energy resources, and some resources are unexploited. Therefore, to balance energy demand and supply, non-conventional resources should be exploited.

The domestic sector consumes maximum biomass-based fuel, 98% of households in the village are using biomass as cooking fuel. The obvious choice of biomass is due to its easy availability. Consumption of the conventional fuel is maximum in the agricultural sector. In the rural sector, there is an increasing demand for electricity and liquefied petroleum gas. The electricity is preferred for all the sectors except for transport, since only the liquid fuel powered automobiles are available in the market. With increase in awareness and availability of conventional fuel, there is a rapid transition from non-conventional to conventional sources of energy. Energy planning is needed for rural sectors for maintaining a sustainable development and meeting the energy demand of peoples, and it involves use of a mix of locally available non-conventional resources blending with some conventional resources. Such efforts can prove a milestone in solving the energy problem of the rural sector and will be economically attractive.

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